Communicating Information on Eruptions and Their Impacts from the Earliest Times Until the Late Twentieth Century

David Chester, Angus Duncan, Rui Coutinho, Nicolau Wallenstein and Stefano Branca

Abstract

Volcanoes hold a fascination for human beings and, before they were recorded by literate observers, eruptions were portrayed in art, were recalled in legend and became incorporated into religious practices: being viewed as agents of punishment, bounty or intimidation depending upon their state of activity and the culture involved. In the Middle East the earliest record dates from the third millennium BCE and knowledge of volcanoes increased progressively over time. In the first century CE written records noted nine volcanoes in the Mediterranean region plus Mount Cameroon in West Africa, yet by 1380 AD the record only totalled 48, with volcanoes in Japan, Indonesia and Iceland being added. After this the list of continued to increase, but important regions such as New Zealand and Hawaii were only added during the last 200 years. Only from 1900 did the rate of growth decline significantly, but it is sobering to recall that in the twentieth century major eruptions have occurred from volcanoes that were considered inactive or extinct, examples including: Mount Lamington—Papua New Guinea, 1951; Mount Arenal—Costa Rica, 1968 and Nyos—Cameroon, 1986. Although there were instances where the human impact of historical eruptions were studied in detail, with

D. Chester (✉)
Department of Geography and Environmental Science, Liverpool Hope University, Liverpool L16 9JD, UK
e-mail: jg54@liv.ac.uk

D. Chester
Department and Planning, University of Liverpool, Liverpool L69 3BX, UK

A. Duncan
Department of Geography and Planning, University of Liverpool, Liverpool, UK
e-mail: A.M.Duncan@liverpool.ac.uk

R. Coutinho · N. Wallenstein
Centro de Vulcanologia e Avaliação de Riscos Geológicos, Universidade dos Açores, Rua da Mãe de Deus, 9501-801 Ponta Delgada, Portugal
e-mail: Rui.MS.Coutinho@azores.gov.pt

N. Wallenstein
e-mail: Nicolau.MB.Wallenstein@azores.gov.pt

S. Branca
Istituto Nazionale di Geofisica e Vulcanologia, 95125 Catania, Sicily, Italy
e-mail: branca@ct.ingv.it

Advs in Volcanology
DOI: 10.1007/11157_2016_30

examples including the 1883 eruption of Krakatau and 1943–1952 eruption of Parícutin, these were exceptions and before 1980 there was a significant knowledge gap about both the short and long-term effects of major eruptions on societies. Following a global review, this chapter provides a discussion of the ways in which information has been collected, compiled and disseminated from the earliest times until the 1980s in two case study areas: the Azores Islands (Portugal) and southern Italy. In Italy information on eruptions stretches back to prehistoric times and has become progressively better known over more than 2,000 years, yet even here there remain significant gaps in the record even for events that took place between 1900 and 1990. In contrast, located in the middle of the Atlantic, the Azores have been isolated for much of their history and illustrate the difficulties involved in using indigenous sources to compile, not only assessments of impact, but also at a more basic level a complete list of historical events with accurate dates.

Keywords
History of eruptions · Increase in global knowledge of eruptions · Volcanoes of Southern Italy and the Azores

1 Introduction: The Global Picture

The purpose of this chapter is two fold. First, to review the communication of information on eruptions and its dissemination from the earliest times until the onset of the 'modern' era of volcanology, which for the purpose of this volume is taken to be the latter part of the 20th century. In the last three decades of the twentieth century volcanology experienced a major change in its scientific status, with events such as the eruption of Mount St. Helens in 1980 and space missions to the terrestrial planets highlighting the important role of volcanism as a planetary process. This in turn focused interest on volcanology and stimulated research funding which, *inter alia*, placed the communication of information on eruptions and their impacts on a more secure footing. The authors are aware that, given the present state of published research, especially on early historic eruptions, this account cannot be truly 'global' and will of necessity be strongly biased towards the acquisition and dissemination of information within countries that are part of the 'western' intellectual tradition, though where possible we have endeavoured to spread the net more widely.

Secondly, the issues surrounding communication will be explored by means of two case studies: the Azores (Portugal) and Mt. Etna in Sicily. These case studies provide good—in some respects contrasting—examples of the ways in which responses to eruptions and their impacts have evolved, from the earliest recorded eruptions to the situation obtaining towards the close of the twentieth century. Although both the Azores and Mt. Etna provide documentary accounts of activity, in each area the distinctive written source and varying eruptive styles and impacts, allow differing insights to emerge. Etna has one of the most extensive records of volcanic activity which stretches over some 2000 years of recorded history. Early accounts from the classical era sought mythical explanations of activity, although some later Greek and Roman writers suggested more rational explanations, though even these were not usually based on detailed observation (Chester et al. 2000). Sicily is located at the centre of the Mediterranean Region and historically had excellent communications with the wider European world. The Renaissance led to the early development of empirical science and a letter, for instance, read to the *Royal Society of London* shows insightful observations of the 1669 eruption of Etna (Anon 1669). In the 19th century and following the eighteenth century Enlightenment, Etna became an important field area for many European scientists, including Carlo Gemmellaro (1787–1866), Charles Lyell (1794–1875), George Poulett Scrope (1797–1876) and Wolfgang Sartorius von Waltershausen (1809–1876), who went on to make major contributions to the understanding of geology and its development as a discipline. More recently, Etna was selected: as one of *decade volcanoes* for detailed interdisciplinary study as part of the United Nations designated *International Decade of Natural Disaster Reduction* (1990–2000); and as a *Laboratory Volcano* jointly sponsored by the *European Economic Communities*[1] and the *European Science Foundation.* In contrast, the Azores have been historically isolated from mainland Europe. Eruptions before the twentieth century did not attract international attention or, indeed, much interest from mainland Portugal. Records were mostly archived locally and generally did not contribute to the development of scientific thinking more widely until the second half of the twentieth century.

2 Communicating Scientific Information: Prehistoric and Historical Perspectives

In the early 1980s it was well established that, even before there were written records of volcanoes and their activity, eruptions were depicted in art, remembered orally and formed part of often elaborate religious rituals, volcanoes being viewed as 'agents of benevolence, fear or vengeance depending on their state of activity and the society involved' (Chester 2005, p. 404; Blong 1982, 1984). In the Middle East, it is often claimed by volcanologists and others that the earliest record of an eruption is a wall painting from the Neolithic town of Çatal Hüyük in Anatolia, showing an eruption with the ejection of blocks and bombs (Mellaart 1967, pp. 59–60, 176–177; Chester 2005). More recently the archaeological team working at the site have concluded that the putative 'volcano' is actually a leopard skin with spots (Hodder 2015, personal communication). The earliest definite records of volcanic activity date, however, from Mesopotamia in the third millennium BCE (Foster 1996; Polinger-Foster and Ritner 1996)[2] and were soon followed by accounts of volcanic activity by Greek, Roman and Islamic writers (Sigurdsson 1999, pp. 14–17).[3] The eruption of Aso volcano in 553 CE was the earliest recorded eruption in Japan (Simkin et al. 1981, p. 66). It occurred a year after Buddhism had been introduced into the country (Keys 1999, pp. 323–324) and may reflect the importance of religious functionaries in providing written accounts about important events.

Most of the data currently available on historic volcanic activity has been collected by the Smithsonian Institution through the *Global Volcanism Program* (GVP), which collates information on current and past activity over the past 10,000 years. Accounts of current activity are provided by the Smithsonian—USGS *Weekly Activity Report*, and comprehensive summaries of past activity are available in the *Bulletin of the*

[1]Now the European Union.

[2]Accounts include 'Starry Mountain' in the Khabur Region. This is probably Kawbab volcano in Mesopotamia (Polinger-Foster and Ritner 1996).

[3]Special attention was paid to Santorini (ancient Thera), Vesuvius and Etna. One of the most significant episodes in Islamic intellectual history was the translation of classical texts into Arabic, some of which included accounts of extreme natural events. This took place in Baghdad and other centres of scholarship between the beginning of the eighth and the close of the tenth centuries CE. In some cases this ensured preservation of important information on eruptions. Especially in Spain, the role of Islamic scholars needs to be acknowledged. Authors, who including the philosopher Ibn Rushd (Latin—Averroes), not only engaged with these texts, but also added their own observations on natural phenomena (Stone 2003; Akasoy 2007).

Global Volcanism Network. These data are periodically archived in successive editions of *Volcanoes of the World* (Simkin et al. 1981; Simkin and Siebert 1994; Seibert et al. 2010). Progress up to the 1980s in both locating volcanoes and cataloguing their eruptions is summarised succinctly in a quotation from the first (1981) edition of *Volcanoes of the World*:

> if a list of… volcanoes had been continually kept, it would, at the time of Christ, have contained only the names of 9 Mediterranean volcanoes and West Africa's Mount Cameroon.[4] In the next 10 centuries the list would have grown by only 17 names, 14 of them Japanese. The first historic eruptions of Indonesia were in 1000 and 1006, and newly settled Iceland soon added 9 volcanoes to help swell the list to 48 by 1380 AD… The list has continued to grow, with several important volcanic regions such as Hawaii and New Zealand being completely unrepresented until the last 200 years. Only in the present century has the *rate* of growth declined significantly (Simkin et al. 1981, p. 23).

Later editions of *Volcanoes of the World* show that advances in knowledge have not slackened and that, whereas in 1981 there were 627 volcanoes with recorded eruptions, by 1994 this figure had risen to 719 and reached 858 in 2010 (Simkin and Siebert 1994; Seibert et al. 2010), largely due to: better monitoring of present day eruptions—especially of those occurring in isolated areas through the use of satellite-based remote sensing; and improved knowledge of events which occurred in antiquity. With regards to the latter, there have been few years in the past three decades that have not seen major publications dealing with pre-historic eruptions, although reviewing these works is beyond the scope of this chapter (see: Firth and McGuire 1999; Sigurdsson 1999; Harris 2000; McCoy and Heiken 2000; McGuire et al. 2000; Balmuth et al. 2005; Grattan 2006; Grattan and Torrence 2007; Oppenheimer 2011).

In terms of better recording, not only has the *Smithsonian Institution* continued its invaluable work since 1981 in collecting eruption information and disseminating it to the volcanological research community, but data especially on human impact has also become more widely available. This was not just from academic authors (e.g. Tanguy et al. 1998; Witham 2005; Cashman and Giordano 2008), but from organizations which have included: the Brussels-based *Centre for Research on the Epidemiology of Disasters* (or CRED); and re-insurance companies, in particular Munich Re (Auker et al. 2013). Advances continue to be made in the second decade of the twenty-first century as witnessed by the new data-base of large magnitude explosive volcanic eruptions (LaMEVE), which forms part of the larger *Volcanic Global Risk Identification and Analysis Project* (VOGRIPA) (Crosweller et al. 2012), and the improved catalogue of fatalities caused by volcanic activity from 1600 to 2010 (Auker et al. 2013).

When examining the written record between 1400 CE when around 50 volcanoes were identified and 1980, when the figure reached 627, there are several points which require more detailed discussion. First, it is clear from the quotation from *Volcanoes of the World* (1981) which is cited above, that progress did not occur at a constant rate during the 580 years which elapsed from 1400 to 1980. There were two periods of marked growth in the list of known active volcanoes: a steady increase from the beginning of the 16th century to the mid-18th century and a second episode of more rapid growth from the mid-18th century to the mid-20th century (Fig. 1). The first period coincides with the *Renaissance* and *Age of Exploration*, especially Spanish and Portuguese penetration into the New World and the invention of the printing press. The second phase reflects a number of developments which include: the easier dissemination of information because of the more widespread use and distribution of printed material particularly newspapers and magazines; the great increase in industrialization, scientific understanding, technology and global trade and the more open intellectual climate associated with the *Enlightenment*.[5] This was facilitated by major advances

[4]Mount Cameroon was first observed in eruption by Hannon, a Carthaginian navigator in the fifth century BCE (Anon 2015).

[5]The *Enlightenment* was an intellectual movement which began in the British Isles in seventeenth century and

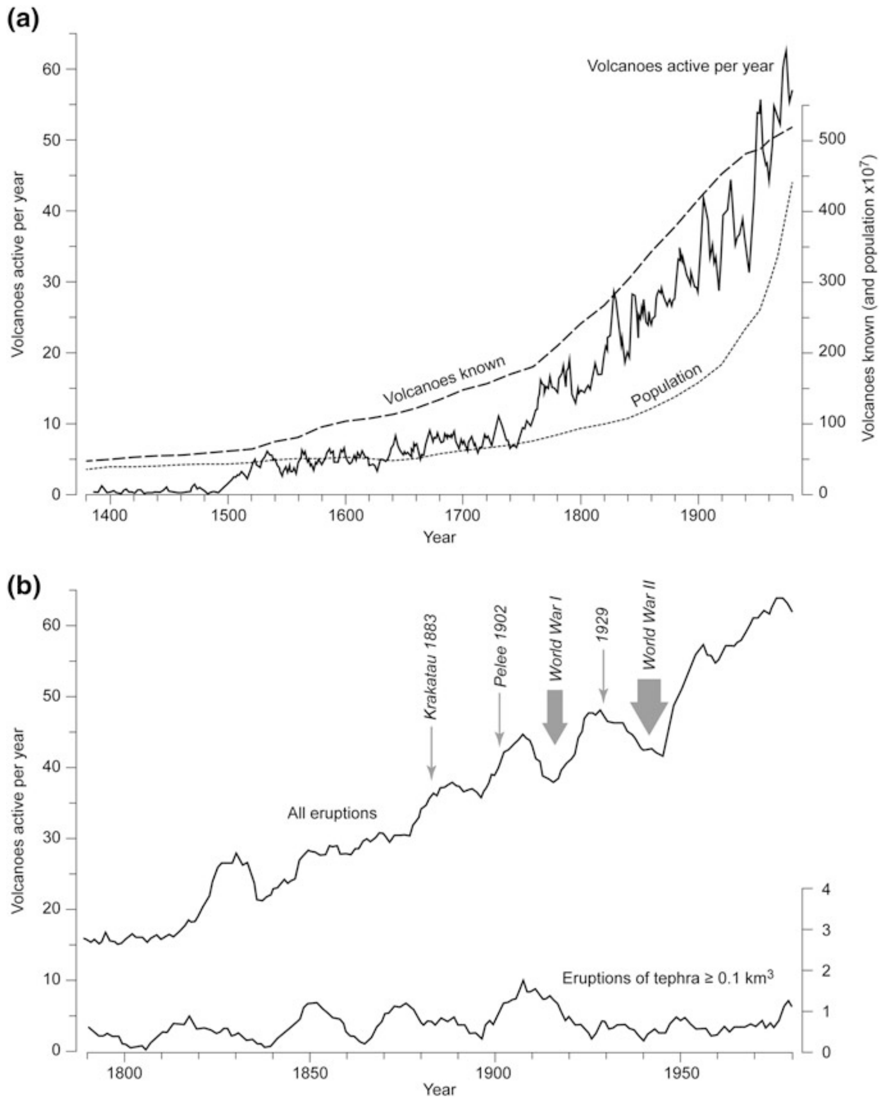


Fig. 1 The reporting of global volcanic activity up to 1980 CE. *Top* known and active volcanoes, and world population 1400–1980. Volcanoes active per year are plotted as a 10 year running mean. 'Volcanoes known' represents the total number to have had historic eruptions. *Bottom* the number of eruptions (*right* hand scale) producing ≥0.1 km^3 of tephra, plotted as a 10-year running mean. Eruptions ≥0.1 km^3 of tephra equates to a *VEI* (i.e. *Volcanic Explosivity Index*) of 4—Newhall and Self (1982). From Siebert et al. (2010, Fig. 9, p. 32 and Fig. 10, p. 33) and reproduced by permission of the University of California Press

in communication; first daily newspapers and from the mid-19th century the electric telegraph. Growth continued up to 1980 as these technologies together with others which came into use—including telex and rapid reliable air-transport—were further developed. By 2010 a flattening in the trend line of the number of volcanoes recorded as active per year, implies

(Footnote 5 continued)
developed in other European and North American countries in the eighteenth century. Its leading doctrines were *inter-alia*: a commitment to reason; the notion of progress, based on education, science and the arts; the rejection of the authority of tradition including religious tradition and a stress on nature which can be studied using empirical methods (Inwood 1995).

Table 1 Eruption catalogues from 1825 to 1981 (based on Simkin et al. (1981), with additional information from the references cited in the table and: Simkin (1993, 1994), Sigurdsson (1999, 2000), Simkin and Siebert (2000), Simkin et al. (2001 and the references cited in the table)

Catalogue (author, date and abbreviated title)[a]	Volcanoes with dated eruptions	Comments
Scrope (1825) *Considerations on volcanoes*	150	From scope's catalogue published in 1825 to that compiled by Schneider (1911), most of the information was derived from archival sources, with relatively little being added from field investigations
von Humboldt (1858) *Kosmas…*	225	
Scrope (1862) *Volcanoes…*	191	
Fuchs (1865) Die *vulkanischen ersheinungun der Erde*	270	
Mercalli (1907) *Vulcani attivi della terra*	231	
Schneider (1911) *Die vulkanischen erscheinungen der Erde*	298	
Sapper (1917) *Katalog der geschichtlichen Vulkanausbruche*	430	From the close of the first decade of the twentieth century, field investigations recognised more and more active volcanoes. The dedicated journal, *Bulletin Volcanologique*, was first published in 1924 and greatly facilitated the dissemination of data collected during field investigations (see below)
Catalogue of active volcanoes of the world (CAVW 1951–1975)	441	In May 1922 at the Rome meeting of the *International Union of Geodesy and Geophysics* (IUGG)[b], proposed a catalogue authored by geologists familiar with particular regions. The *Great Depression* of the 1930s and the Second World War delayed this project until the 1950s. Later in 1960 the IUGG decided to publish a *Bulletin of Volcanic Eruptions* to record eruptions each year. Reports were compiled by the *Volcanological Society of Japan* and publishing in *Bulletin Volcanologique*
Lamb (1970) *Volcanic dust in the atmosphere…*	435	Compiled to study eruptions of meteorological significance
Macdonald (1972) *Volcanoes*	516	
Gushchenko (1979) *Eruptions of the volcanoes of the world…*	609	
Simkin et al. (1981) *Volcanoes of the world*	627	This catalogue grew out of the *Smithsonian Center for Short-Lived Phenomena* (CSLP) which as set up in 1968. In 1975 the Smithsonian incorporated the CSLP into the Washington-based *Scientific Event Alert Network* (SEAN), which published a monthly bulletin of eruptions and summarised these in the journal *Geotimes*. The full SEAN was available through subscription

[a]There is also the catalogue of von Hoff and Berghaus (1840/41). This is not included because the coverage of not global, but is strongly biased towards the 'old world'
[b]Later this became the *International Association of Volcanology and Chemistry of the Earth's Interior* (IAVCEI)

that virtually all volcanic eruptions on land have been identified (Seibert et al. 2010).

With respect to the scientific community, communication was greatly facilitated by the publication of summary catalogues. In the 17th century, the pioneering work of Bernhardus Varenius (1650)[6] was noteworthy, but from the beginning of the 19th century the number of catalogues burgeoned (Table 1), being formalized in the mid-20th century with the publication of the *Catalog of Active Volcanoes of the World* (1951–1975). As Table 1 shows, in the early

[6]A German geographer, who was also known as Bernhardus Varen (1622–1650), worked mostly in Amsterdam. He was aware of the discoveries of many contemporary Dutch navigators. He listed 21 volcanoes with dated eruptions (Simkin et al. 1981: 1).

1980s communication was still dominated by paper-based media with circulation being restricted to academic institutions and government research organisations who were both willing and had the financial means to subscribe to learned journals and reports.

Several authors the majority of whom are or have been associated with the *Smithsonian Institution* (Simkin 1993, 1994; Simkin and Siebert 2000; Simkin et al. 2001), have commented further on the historic trends plotted in Fig. 1. They note, *inter alia*:

a. That the increase in the number of active volcanoes[7] over time is related to growth in the world's population and better communications, and not to any increase in the frequency of volcanic activity.
b. When the period from ca. 1800 is examined in more detail (Fig. 1) peaks and troughs become apparent. Peaks can be seen to follow newsworthy eruptions such as the three large magnitude events of 1902 (i.e. Mont Peleé, Martinique; La Soufriére, St. Vincent and Santa Maria, Guatemala) and Krakatau, Indonesia in 1883. Simkin and Siebert (1994) argue that such peaks are due to increased post-eruption reporting when there was a heightened awareness of activity. Not only did these eruptions produce voluminous newspaper reports in many countries, the London *Times* for example publishing 14 reports on Krakatau alone some of them very detailed,[8] but also major scientific studies (e.g. Lacroix 1904; Verbeek 1884). Troughs, in contrast, coincide with the disruption of global science brought about by the First and Second World Wars, and the Great Depression of the 1930s which followed the Wall Street stock market crash of 1929.
c. One measure of the incomplete character of the eruption archive before the last few centuries, is that even the record of large eruptions decays rapidly from an average of more than 5 per decade in recent centuries to 0.7 per decade before the 15th century (Simkin and Siebert 1994). Other studies of underreporting have been published by Deligne et al. (2010) and Furlan (2010).
d. Fatal eruptions are far more likely to be preserved in the historical record than non-fatal ones (Simkin et al. 2001). For eruptions occurring since 1500 CE, detailed information on human impacts is generally more sparse than data on eruptive processes and their effects, although this inbalance was beginning to be redressed albeit in an inchoate fashion in the years leading up to 1980 (e.g. Furneaux 1965; Nolan 1979; Simkin and Fiske 1983; Blong 1984).
e. In many part of the world eruption records are short—often less than one hundred years—whereas repose periods of many volcanoes are much longer (Tazieff 1983). This means that even in the decades immediately before 1980, several large eruptions occurred from volcanoes which were thought by local populations to have been inactive. Examples included: Mount Lamington, in Papua New Guinea which killed ca. 5000 people in 1951; Mount Arenal (Costa Rica) in 1968 and Heimaey (Iceland) in 1973 (Chester 2005). This raises the important question of how scientists can effectively communicate risk to communities who do not consider a given volcano to be active. Long repose is often associated, moreover, with the silicic volcanism of subduction zones, regions in which there are dense clusters of population.

Discussion of the historic increase of information about volcanoes and their eruptions has been focused so far at the global scale, but in the sections that follow progress will be reviewed with reference to the two case studies: the Azores in Portugal and Mount Etna, Sicily (southern

[7]An active volcano is frequently defined as one showing historic activity. This definition introduces a lack of consistency, because the span of historic records varies across the world from thousands to less than 200 years. We follow *Volcanoes of the World* in including volcanoes with dated eruptions that have occurred during the Holocene i.e. the last 10,000 years (Simkin and Siebert 1994, p. 12).

[8]These are available electronically from *The Times Digital Archive*—last accessed 9/5/14.

Italy). Although the general trends already identified are present and, while both regions are culturally southern European, here the similarity ends and their histories are contrasting in terms of both the recording and communication of data on eruptions. The Azores Islands for most of their history have been characterised by isolation; both geographic and intellectual. Located in the middle of the Atlantic Ocean, the islands were only settled in the 15th century and for much of their subsequent history have never held a central or even a secondary place within the scientific mainstream. The Azores exemplify the difficulties of using indigenous data sources to compile, not just assessments of impact but, also at a more basic level, a complete list of events with accurate dates. Many of the accounts which are available were collected by a limited number of literate observers, who were often priests, and require much careful interpretation to extract usable information on eruption processes and their effects.

In contrast, information on Mount Etna and its eruptions stretches back to prehistoric times and has become progressively better known over more than 2000 years of written history. In Greek and Roman times it was at the centre of attempts by classical authors to make sense of the natural world with interpretation often involving aspects of mythology (Chester et al. 2000), in the *Renaissance* major studies of Etna and its eruptions were published, the *Enlightenment* and the nineteenth century saw the volcano being studied by both indigenous and distinguished foreign scientists of the calibre of Sir William Hamilton, Charles Lyell and Sartorius von Waltershausen and this continued through to he 1980s. Etna and Vesuvius were part of the European Grand Tour, Sicily was strategically important during the Napoleonic Wars, later in the nineteenth century visits to the volcano were eased by the spread of railways and stream ships and, following the introduction of the electric telegraph, educated appetites in the USA and Western Europe could be satisfied by detailed reports in newspapers of record which often appearing only hours after the events being described (Chester et al. 1985, 2012). Yet even on Etna significant gaps remained in the record—not least on human impacts—even for events that took place between 1900 and 1980.

3 The Azores: Communicating Eruption Information from an Isolated Region

The settlement of the Azores was part of the voyages of discovery undertaken by Portuguese navigators from the 15th century and, although there is debate over whether or not there were earlier visitors to the islands (Ashe 1813; Admiralty 1945; De Meneses 2012), it is generally accepted that in the autumn of 1431 an expedition led by Gonçalo Velho Cabral established a settlement on Santa Maria and that by 1457 all nine islands were known (Fig. 2). Indeed the arrival of the first settlers on São Miguel ca. 1439–1443, probably coincided with the dome-forming final stage of a sub-plinian phreatomagmatic eruption of Furnas volcano (Queiroz et al. 1995; Guest et al. 1999). Between settlement of the archipelago and 1980 a further 26 eruptions took place (Fig. 2 and Table 2), with one subsequent submarine occurring between 1998 and 2001 (Gaspar et al. 2015).

The communication of information about eruptions was not marked by steady progress and even in the second half of the 20th century there were still major gaps in the record. For instance the Azores volume of the *Catalogue of Active Volcanoes of the World* was published in the 1960s (Neumann van Padang et al. 1967), but when compared with what is known today (Gaspar et al. 2015) shows a lack of detail about the volcanological character of historic events, human impact is ignored and some eruptions—most notably that of ca. 1439–1443—are absent. Another standard reference from the period (Weston 1964), also ignores the ca. 1439–1443 event, lists an eruption of Sete Cidades (São Miguel Island) in 1439 that did not occur and reports a lava flowing in the direction of Rabo de Peixe (São Miguel Island) in 1652 which is incorrect. Maps and memoirs produced by the

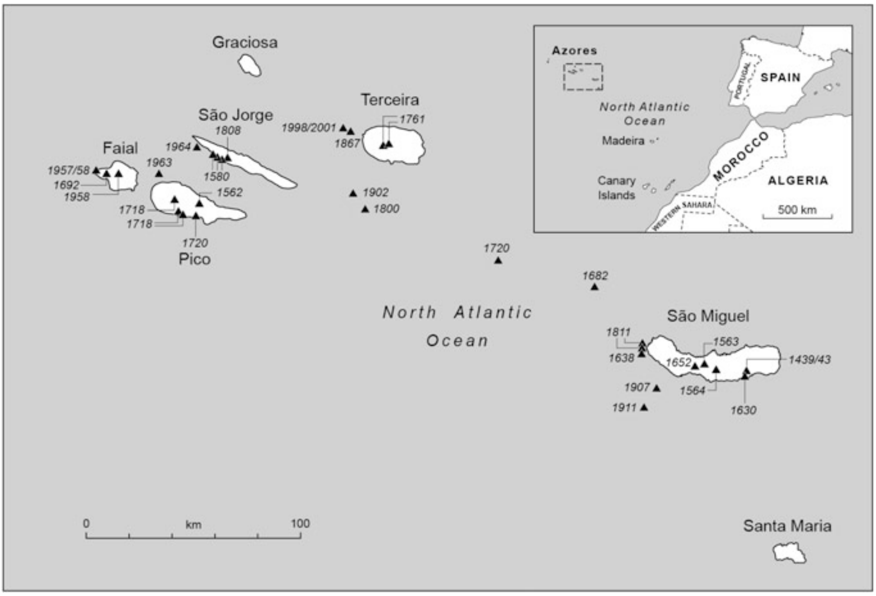


Fig. 2 The Azores archipelago: general location and the position and dates of historic eruptions (data from Gaspar et al. 2015)

Serviços Geológicos de Portugal[9] (e.g. Zbyszewski et al. 1958, 1959; Zbyszewski 1961) were published as part of the 1:50,000 scale mapping of Portugal and the Atlantic Islands and are likewise partial in their treatment of historical eruptions and their impacts.

Between 1950 and 1980 a few studies of past eruptions were published in international scientific journals, but these were either focused on: the most recent 1957/8 phreatomagmatic eruption at Capelinhos on Faial Island, but again strongly themed on volcanological aspects rather than human impacts (e.g. Machado et al. 1962); or concerned large plinian events that took place long before the islands were settled and are, therefore, outside the scope of this review (e.g. Walker and Croasdale 1971; Booth et al. 1978). Establishing a detailed record such as that provided by Gaspar et al. (2015), requires detailed analysis of all accessible archival sources and its cross-checking with field evidence so that historical accounts may be either verified or eliminated.

Although the Azores lie some 1360 km to the west of the coast of Portugal, lack of transmission of information cannot be blamed solely on physical isolation. Admittedly before the era of mass air transport visiting the islands was difficult and time consuming, but in comparison with other mid-oceanic islands seaborne communication was well developed, with the ports of Ponta Delgada (São Miguel), Horta (Faial) and Angra do Heroísmo (Terceira) in particular being important staging posts in Atlantic trade. In the era before steam power the agricultural economy of the archipelago was highly specialized and was concerned not only with subsistence, but also with provisioning the many ships that visited the islands (Admiralty 1945; Callender and Henshall 1968). The volcanoes of the Azores tend to give rise to short-lived subaerial activity with activity lasting no more than few days or weeks, and in the 17th and 19th centuries there is little evidence that the eruptions of: Pico 1718 and 1720; Terceira 1761 and São Jorge 1808,

[9]Later part of the *Instituto Geológico Mineiro* (Institute for Geology and Mining), from 2004 to 2007 the *Instituto da Engenharia Tecnologia e Inovação* (Institute of Engineering Technology and Innovation) and, thereafter, the *Laboratório Nacional de Energie e Geologia* (National Laboratory of Geology and Energy).

Table 2 Major eruptions on the islands of the Azores: 1439/1443 to 1980 CE (Based on Gaspar et al. 2015)

Eruption date	Location	Characteristics of eruption
1439/1443	Furnas volcano, S. Miguel	Sub-plinian, phreatomagmatic associated with trachytic pumice and a lava dome
1562–64	Fissural System, Pico	Hawaiian and strombolian activity, producing lava flows and pyroclasts
1563	Fogo volcano, S. Miguel	Sub-plinian, phreatomagmatic eruption. Products include trachytic pumice lapilli/ash and surges. Two deaths due to gas inhalation
1563	NW Flank of Fogo volcano, S. Miguel	Hawaiian activity, with basaltic lava flows, spatter and pyroclasts
1564	Fogo volcano, S. Miguel	Phreatic
1580	Manadas Fissural System, S. Jorge	Hawaiian/strombolian activity, producing lava flows and a pyroclastic flow. About 15 deaths
1630	Furnas volcano, S. Miguel	Sub-plinian/phreatomagmatic eruption, associated with lava domes, pumice, ash/lapilli, lava domes and pyroclastic density currents. At least 195 deaths from surges and collapsed buildings
1638	Candelária submarine volcano, S. Miguel	Surtseyan
1652	Picos Fissural System, S. Miguel	Vulcanian—ashes, blocks, lava domes and flows
1672–1673	Capelo Fissural System, Faial	Basaltic lava flows and pyroclasts. A least 3 deaths and around 1200 persons displaced
1682	Crista João Valadão Submarine Volcanic System, off the west coast of S. Miguel	Few details
1718	Pico Volcano	Hawaiian and strombolian eruption, producing submarine and sub-aerial pyroclasts and lava flows. 2 deaths
1720	Fissural Volcanic System, Pico	Basaltic pyroclastic and lava flows
1720	D. João de Castro Submarine Volcano, between S. Miguel and the Central Islands	Surtseyan
1761	Santa Bárbara Volcano, Terceira	Vulcanian (?) Trachytic ashes, blocks and lava domes
1761	Terceira Fissural Volcanic System	Hawaiian and strombolian activity, producing basaltic bombs, lapilli, ash and lava flows
1800	Submarine SSW of Terceira	?
1808	Manadas Fissural Volcanic System, S. Jorge	Hawaiian/strombolian and phreatomagmatic. Basaltic lapilli/ash, lava and pyroclastic flows. More than 30 deaths
1811	Sabrina Submarine Volcanic System, S. Miguel	Basaltic submarine eruption, ash and blocks
1867	Crista da Serreta Submarine Volcanic System, west of Terceira	Basaltic submarine eruption
1902	Submarine, SW of Terceira Island	?
1907	Submarine, SW of S. Miguel Island	?
1911	Submarine, SW of S. Miguel	?
1957/8	Capelo Fissural Volcanic System, Faial	Surtseyan, hawaiian and strombolian activity. Submarine and sub-aerial basaltic pyroclasts, surges and lava flows
1958	Caldera Volcano, Faial	Phreatic and phreatomagmatic. Ash produced
1963	Cachorro Submarine Volcano, offshore, north of Pico	Submarine activity
1964	Velas Submarine Volcano, S. Jorge	Submarine activity
1998/2001	Crista da Serreta Submarine Volcanic System, west of Terceira	Submarine lava balloons, submarine ashes and volcanic gases

attracted interest from outside the islands. Volcanoes on the Azores did not show phases of persistent activity as was the case with volcanoes like Etna or Vesuvius and this, together with isolation, may explain the lack of foreign visitors. It is interesting to note that a detailed description of a submarine eruption in June 1811, which occurred off the shore of São Miguel, was undertaken by the captain of a Royal Navy frigate and communicated to the *Royal Society of London* (Tillard 1812). This report was fortuitous because the ship was in the area by pure chance and the eruption was named *Sabrina* after the frigate. In the 1890s the islands (and especially Faial) became major nodes on the worldwide telegraph network, with personnel from Germany, the UK and USA being billeted on the islands particularly in Horta the principal settlement of Faial. Despite ships and later telegrams arriving in Europe and North America on a daily basis searches of newspapers of record—such as the London *Times* (1785–2008) and *New York Times* (1851–2007) and daily publications of a more popularist character contained no eruption reports until well into the 20th century, although it must be admitted that between 1808 and 1957/58 there were no eruptions on land, only a number of submarine eruptions. The 1957/58 eruption of Capelinhos, Faial (Coutinho et al. 2010) was the first to be covered in any detail.[10]

Isolation may take several forms and in the Azores was expressed intellectually, scientifically and politically. In Portugal both the institutional and professional development of science and more particularly the geological sciences, lagged behind that in other European countries and greatly inhibited the contemporary collection and transmission of eruption data. In a devoutly Catholic country it might be thought that the development of geology would have been inhibited by religious considerations, especially following the publication of Lyell's *Principles of Geology* and in 1830 Darwin's *Origin of Species* in 1859, but as Carneiro et al. (2013) have argued this was not the case. Universities had been outside religious jurisdiction since 1772 and there was a long tradition of independence between science and religion among educated elites across Portugal. In the second decade of the twentieth century, 'despite the close relationship between the newly established regime[11] and the Roman Catholic Church, António Salazar (1889–1970) maintained the separation of Church and State; in addition, the State held no official position regarding scientific matters' (Carneiro et al. 2013, p. 333).

As Mota and Carneiro (2013, p. 24) have noted, 'despite the creation of the national geological survey being coeval to other European countries, the teaching of geology and geological research became effective only as late as the mid-twentieth century and the Portuguese Geological Society was only founded in 1940.' In addition until 1911 there was only one university in Portugal at Coimbra, after this Oporto and Lisbon were added and the University of the Azores only dates from two years after the Portuguese Revolution of 1974. Until well into the twentieth century, people—almost invariably men—who wanted careers in science only had three choices: 'medicine; the clergy; and, in the nineteenth century, military engineering' (Carneiro et al. 2013, p. 332).[12]

[10]The *London Times*, *Nineteenth Century British Library Newspapers* and *Nineteenth Century US Newspapers* are available from Gale *GENGAGE*—see Footnote 4. The New York Times is available from ProQuest http://www.proquest.com/. Accessed 16 May 2014. It is interesting that, in contrast to eruptions, Azorean earthquakes were extensively reported in the international press. Earthquakes frequently caused death and destruction to places in the Azores visited by European and North American seafarers and, in the nineteenth century alone, earthquakes of intensity VIII or greater affected Terceira in 1800, 1801 and 1841 and São Miguel in 1810, 1811 and 1852.

[11]This is the authoritarian *Estado Novo* regime (1928–1974) which was led by António Salazar until 1968.

[12]It is notable that neither of the two leading figures in Azorean volcanology in the first six decades of the twentieth century was a geologist by training. José Agostinho (1888–1978), who published on a variety of volcanological topics (e.g. Agostinho 1932) was an army officer and meteorologist. Frederico Machado (1918–2000) was a civil engineer, who made notable contributions to both recording and managing the 1957/8 eruption and earthquake on Faial Island (Machado et al. 1962).

A lack of trained personnel and of focused science policy can be clearly seen as late as the 1950s. By the time of the Capelinhos eruption (Faial—1957/58), the current authors have noted that leading roles were played by engineers and other professionals, rather than geologists and that the regime was open to and encouraged scientific enquiry, which was financially supported and involved both Portuguese and foreign scholars. There were no 'in-depth studies of the impacts of and government responses to the emergency. Evaluative and potentially critical studies of policy were not welcomed by the government' (Coutinho et al. 2010, p. 266).

These features of Portuguese intellectual history meant that in the Azores the intellectual elite, who included State officials, was diligent in recording eruptions in locally published books, monographs, academic journals and freely discussed scientific ideas—including geological advances—in the local press. They did not, however, disseminate information more widely. Many early eruptions and their effects were recorded by the priest historian, Gaspar Frutuoso (ca. 1522–1591—Fig. 3), in Book IV (São Miguel) and Book VI (Terceira, Faial, Pico, Flores, Graciosa and São Jorge) of his multi-volume work: *Saudades da Terra* (English translation—*A Nostalgic Longing for the Land*—Frutuoso 2005). This work remained in manuscript form until the late nineteenth century, was published from 1873 onwards (Luz 1996) and did not become widely available outside Portugal until much later. For instance, in the United States the *Library of Congress* Catalogue only lists Book IV (1876) before the complete work appears in 1978, while in the UK the position is only slightly better with only three locations being listed for the 1873 edition.[13]

Later in the nineteenth century the historian and politician Ernesto do Canto[14] (1831–1900—Fig. 3), collected many accounts of historical eruptions and published these in a journal, *Arquivo dos Açores*, which he both launched and printed. This publication had limited dissemination outside the Azores and in fact has only been widely accessible since it has become available in digital form from the University of the Azores (http://www.sdoc.uac.pt/pt/publicacoes).

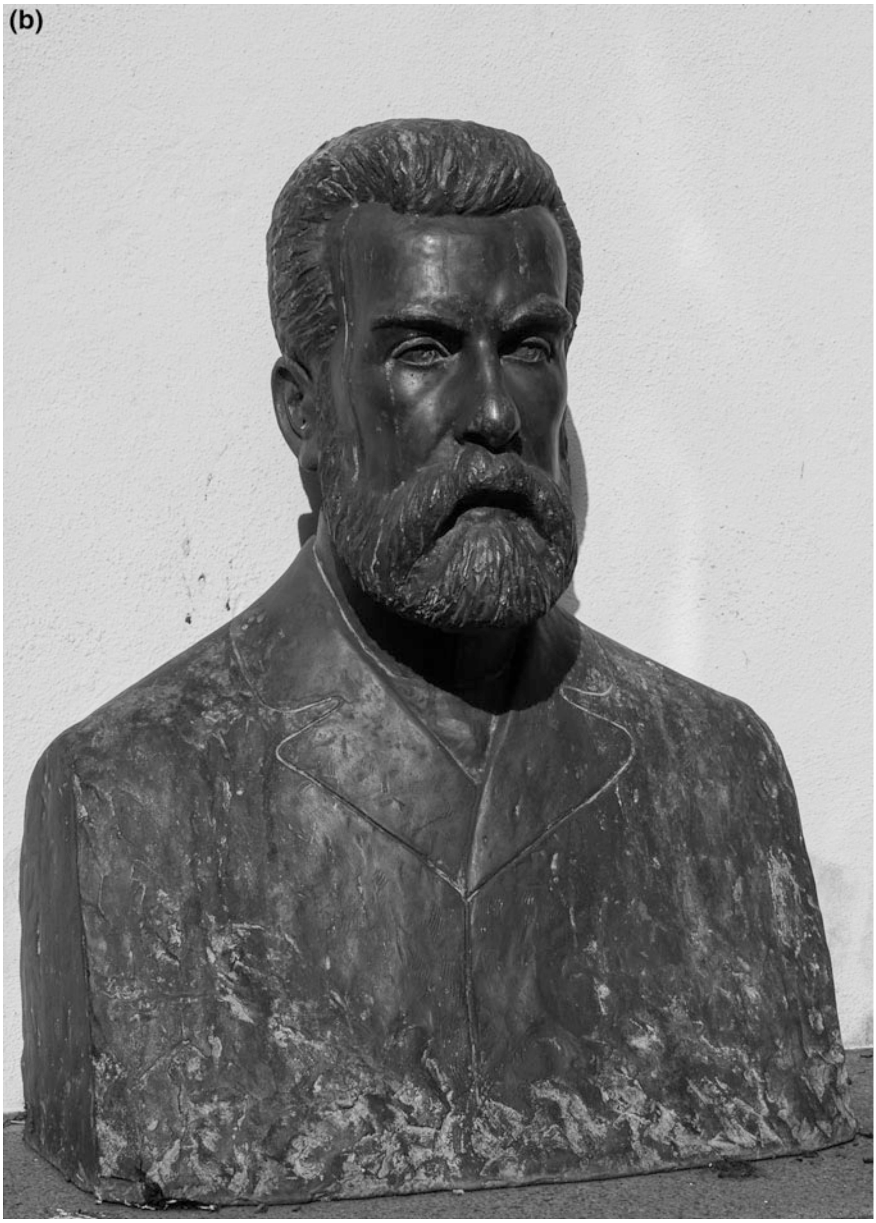
The role of the press in reporting science in general and particularly natural events has recently been reviewed by Simões et al. (2012). Although rates of illiteracy in Portugal were ca. 79% in 1900, in 1894 there were 23 newspapers and periodicals published in Ponta Delgada (São Miguel), the capital of the Azores, which were read by the elite and made available for public readings in taverns, cafes and shops. In reviewing one newspaper, the progressive *Diário dos Açores*—founded in 1870, Simões et al. (2012, p. 314) show how science was extensively reported, with the motivation being 'an attempt by the scientific and political communities to gain the support of the general public'. Although hygiene and public health were the dominant themes, there was also reporting of geological topics, with the Messina earthquake of 1908 being afforded extensive coverage. Indeed following the 1909 Benavente earthquake near to Lisbon (Degg and Doornkamp 1994), there was lobbying for a seismic network to be established on the islands and, indeed, two seismological stations had been set up in the Azores in 1902; one at Ponta Delgada and the other at Horta. Although the *Diário dos Açores* contains coverage of volcanology, progressive lobbying through the paper was less successful than was the case with earthquakes and did not lead to any significant new research being undertaken on contemporary activity, or the impacts of historical eruptions becoming more widely known (see Simões et al. 2012, pp. 318–325). It is perhaps not coincidental that eruptions in the second half of the 19th and the early 20th centuries were small-scale submarine events and the loss of 200 houses and landslides in Terceira in 1866 was caused by volcano-related seismic activity, rather than by volcanic activity per se (Gaspar et al. 2015).

[13]Oxford and Cambridge University libraries and the library of Kings College London.

[14]Also known as Ernesto do Canto e Castro.

Fig. 3 Two pioneers of Azorean volcanology. **a** Statue (*left*) of Gaspar Frutuosa at Ribeira Grande (São Miguel) his place of birth ca. 1522. He was the son of a local landowner and trained for the priesthood at the University of Salamanca (Rodrigues 1991). **b** Photograph of Ernesto do Canto in 1884 (*right*). Canto was a notable Azorean intellectual and was born into one of the most influential families on the islands. As well as founding the *Arquivo dos Açores*, Canto was member of the Portuguese *Academy of Sciences*, the *Lisbon Geographical Society* and made valuable donations to the public library in Ponta Delgada. For further details of his life and work see Dias (1931). Photographs Nicolau Wallenstein

Fig. 3 (continued)



4 Mount Etna, Sicily: The Accumulation of Knowledge Over 2000 Years

The volcanoes of Italy and especially Etna and Vesuvius were amongst the first to be known to literate European observers. Etna (Fig. 4) a huge volcano in comparison with Vesuvius, covering an area of 1178 km^2 and standing 3328 m in height (Branca et al. 2011), was virtually continually in eruption during classical times, with activity being typically effusive and strombolian in character, though there were more explosive events such as the plinian eruption of 122 BCE which produced considerable tephra fall and caused severe damage in Catania (Coltelli et al. 1998). Although most activity occurred away from inhabited areas, at

Fig. 4 Mount Etna: location map

times larger flank eruptions caused widespread destruction. Etna and its eruptions feature in the literature of the classical age through reflections of a predominantly mythological and legendary character and, indeed, a list of authors includes some of the era's greatest writers (see Chester et al. 2000; Duncan et al. 2005; Johnston 2005; Smolenaars 2005). Records of eruptions can also be extracted from Greek and Roman sources, particularly the works of Pindar, Diodorus Siculus, Thucydides, Virgil, Pliny the Elder, Suetonius, and Lucretius, but as Branca and Del Carlo (2004, pp. 2–3) have noted: only major eruptions were recorded; information has often to be 'translated from poetic language into hard fact'; there is an issue in linking eruption reports to deposits found in the field and, although some eruptions are associated with important historical events—most notably the death of Julius Caesar in 44 BCE—before the 17th century the dating of the lava flows is problematic. The publication of the new 1:50,000 scale map of Etna in 2011 acted as a stimulus for ancient texts to be examined afresh. New dates for eruptions occurring in the classical and medieval eras have been proposed, that are supported by both archaeomagnetic and radiometric dating of volcanic products (Branca et al. 2011; Tanguy et al. 2012) and which allows a comprehensive eruption history to be defined for the last 2500 years.

What Branca and Del Carlo (2004: 2) have termed the *ancient period* continued until the 11th century and the end of the era of Islamic[15] domination of Sicily. Thereafter until the close of the 12th century, there was Norman control of Sicily that in the 13th century gave way to Spanish domination which broadly coincides with the *Renaissance*. Two decades ago it was thought that the record of flank eruptions was fairly robust from the 14th century (Romano and Sturiale 1982), though there was questioning of the status of some 16th and early 17th century eruptions by Chester et al. (1985, Table 3.3), but on the basis of information collected during the construction of the 2011 geological map this conclusion can no longer be sustained. As Branca and Del Carlo (2004, p. 5), note 'we can only be certain about eruptions that occurred below 1800 m …on the southeastern flank, because information on volcanic activity was only available in the cultivated and inhabited zones on the outskirts of Catania' (Fig. 4). In spite of this lack of comprehensiveness, knowledge of Etna's eruptions improved greatly especially from the start of the 16th century and mirrored the pattern for the *Renaissance* in general, with the more widespread dissemination of printed volumes written by distinguished polymaths such as: Fazzello (1558),[16] Filoteo (1590),[17] and Carrera (1636).[18] From 1600, a growing interest in the natural sciences meant that almost all flank eruptions—though not all summit activity—was recorded. In fact geological and archaeomagnetic data have revealed that some flank eruptions in the 17th century, and in the late 18th and early 19th centuries some events on the upper northwest flank, were not recorded in contemporary sources (Tanguy et al. 2012). As noted in the introduction large eruptions stimulate research, reporting and communication and the 1669 eruption was no exception. Etna's most voluminous historical event, the 1669 eruption, devastated the south-eastern flank of the volcano, destroyed the western part of Catania, the large village of Nicolosi and many smaller settlements (Fig. 4). It was reported by Sicilian and mainland Italian authors (Monaco 1669; Squillaci 1669; Tedeschi Paternò 1669; Borelli 1670), together with foreign writers (e.g. Anon 1669; Winchilsea 1669).[19] There were reports at the time in international scientific publications (e.g. *Gazette de France* and the *Philosophical Transactions of the Royal Society of London*). These sources provide descriptive material on aspects of the eruption and some of its immediate impacts. Recently, Branca et al. (2015) have undertaken a detailed study of this material which shows that the impact of the 1669 eruption was complicated by the catastrophic earthquake that devastated eastern Sicily in 1693.

Following 1669 and reflecting the strong empirical interest in nature which characterized the *Enlightenment* (see Footnote 4), the manner of describing eruptions changed and became more detailed, complete and for the first time summit activity began to be recorded, though it was not until the establishment of the Etnean Volcanology Institute by Gaetano Ponte in 1926, that this was undertaken in a systematic manner (Branca and Del Carlo 2004, p. 3). Within this tradition two major studies were published by Recupero (1815) and Ferrara (1818). They included observations made during the late 18th century and earlier and their publications were widely distributed across western Europe, appearing in library catalogues in France and Great Britain. An increasing number of foreign visitors were arriving in Sicily. At the start these were young aristocrats and other equally wealthy tourists who were experiencing the *Grand Tour* of classical sites and historic cities. Some took an active interest in and published widely on Etna (Vaccari 2008), most notably the Scot Brydone (1773) and later

[15]It is often termed the Arabic period, but the Islamic settlers also included Berbers and Spanish Muslims.

[16]Tommaso Fazzello (or Fazello) 1498–1570—Priest, historian and orator and known as the father of Sicilian history (Anon 2014a).

[17]Antonio Filoteo (unknown—1573)—Jurist and historian. Also known as Antonio Filoteo Degli Omadei. (Anon 2014b).

[18]Pietro Carrera (1573–1647)—Chess player, priest, historian and Italian author (Anon 2014c).

[19]The English Earl of Winchilsea (1669) was sailing off the coast of Etna at the time of the eruption. An *English Merchants' Report* to the *Royal Society of London* (Anon 1669) was sent by business men resident in Sicily.

during the brief British occupation of Sicily (1806–1815) an officer visiting the volcano sent home a report of the 1809 flank eruption which was subsequently published in a Scottish newspaper (Anon 1809). By the time of the 1865 flank eruption visits by foreigners were well established, were facilitated by the advent of railways and are described as 'pouring into the region'(Anon 1865). In fact this event was the first eruption to be photographed by the Frenchman, Paul M Berthier, who accompanied the volcanologist Orazio Silvestri in a visit to the vent (Abate et al. 2013). By the early years of the 20th century, 'dark tourism' was causing problems for the authorities in managing the visitor influx (Anon 1923).[20] Tourism stimulated a thirst for news first in Europe and later in the USA, and during the course of the 19th century there was marked increase in eruption reporting in both newspapers of record and in the more popular press (Chester et al. 2012).

During the 19th century rational investigation of Etna made a significant contribution to understanding within the earth sciences. This is an apparent paradox, because in a devoutly Catholic region in which every eruption was and is still associated with elaborate rituals supposedly to assuage divine wrath (Chester et al. 2008), *Enlightenment* science prospered so well. Giuseppe Recupero (1720–1778), Francesco Ferrara (1767–1850) and later Giuseppe Alessi (1774–1837) were priests yet, with one exception, encountered no opposition from the ecclesiastical hierarchy. The exception was Canon Recupero (Fig. 5), famous for his published work and for introducing the Naples-based diplomat and volcanologist Sir William Hamilton to Etna. Many years before the publication of Lyell's *Principles of Geology* (1830), Recupero speculated about some lavas being much older than the generally accepted biblical chronology for the age of the earth. Brydone (1773, p. 132) writes:

> Recupero tells me he is exceedingly embarrassed, by these discoveries…. Moses[21] hangs like a dead weight upon him, and blunts his zeal for inquiry; for that really he has not the conscience to make the mountain so young, as that prophet makes the world. What do you think of these sentiments from a Roman Catholic divine? The bishop, who is famously orthodox …. has already warned him to be upon his guard; and not to pretend to be a better natural historian than Moses; not to presume to urge anything that may in the smallest degree be deemed contradictory to his sacred authority.

Clearly observation and study of the natural world—God's created order—was acceptable, but speculation about its origin and when it came into existence was not. Following the publication of Brydone's book Recupero was censured and lost his canonical preferment (Rodwell 1878).

Giuseppe Alessi was also a priest/scientist and published extensively on Etna and its eruptions (Alessi 1829–1835), but in the first half of the 19th century the baton passed to secular scholars, in particular to the brothers Gemmellaro (Mario 1773–1838, Carlo 1787–1866 and Giuseppe 1788–1876). Between them the brothers observed and described Etna's activity and speculated about its volcanic phenomena (Guest et al. 2003, p. 180), Giuseppe accompanying Lyell on his visits and Carlo producing a major academic study (Gemmellaro 1858). Lyell's *Principles of Geology*, his theory of uniformitarianism and the methodology espoused by him and other leading contemporary geologists of the time, found ready acceptance in Italy (Vaccari 1998) and by the close of the century, not only was the eruptive history of Etna known in considerable detail from ca. 1600, but flows had been mapped with accuracy most notably by the German geologist Wolfgang Sartorius von Waltershausen. The 1:50,000 map produced by Waltershausen, was published as the *Atlas des Aetna* (von Waltershausen 1844–1859) and was the world's first geological map of a large active volcano. A scholarly society, the *Accademia Gioenia*,[22]

[20]Dark tourism involves visits to sites associated with death, war and other tragedies. Not all the tourism was 'dark', however, and major studies were published by some visitors not least Rodwell (1878).

[21]It was generally accepted at the time that Moses was the author of the Pentateuch, the first five books of the Old Testament or Hebrew Bible, beginning with Genesis.

[22]The academy was named after the Sicilian scholar, Giuseppe Gioeni d' Angio (1743–1822).

Fig. 5 Two pioneers of Etnean volcanology. **a** Canon Giuseppe Recupero (1720–1778). **b** Alfred Rittmann (1893–1980). *Photographs* Stefano Branca and the *Istituto Nazionale di Geofisica e Vulcanologia* (INGV), Catania

was established in Catania in 1824, many leading geologists were members and its journal quickly found a place in the libraries of learned societies and major universities in Italy and across Europe.

The years from ca. 1850 to 1928, the year in which the well studied eruption destroyed the village of Mascali, were ones of consolidation. Major flank eruptions occurred in: 1852/3; 1865; 1879; 1883; 1886; 1892; 1910; 1911 and 1923, and there were progressively more detailed accounts in newspapers of record particularly in the United States and United Kingdom. Sicily was first linked to the Italian mainland by the electric telegraph in the 1850s, with the first reliable trans-Atlantic links dating from a few years later (Chester et al. 2012, pp. 75–76). By the twentieth century, newsreels

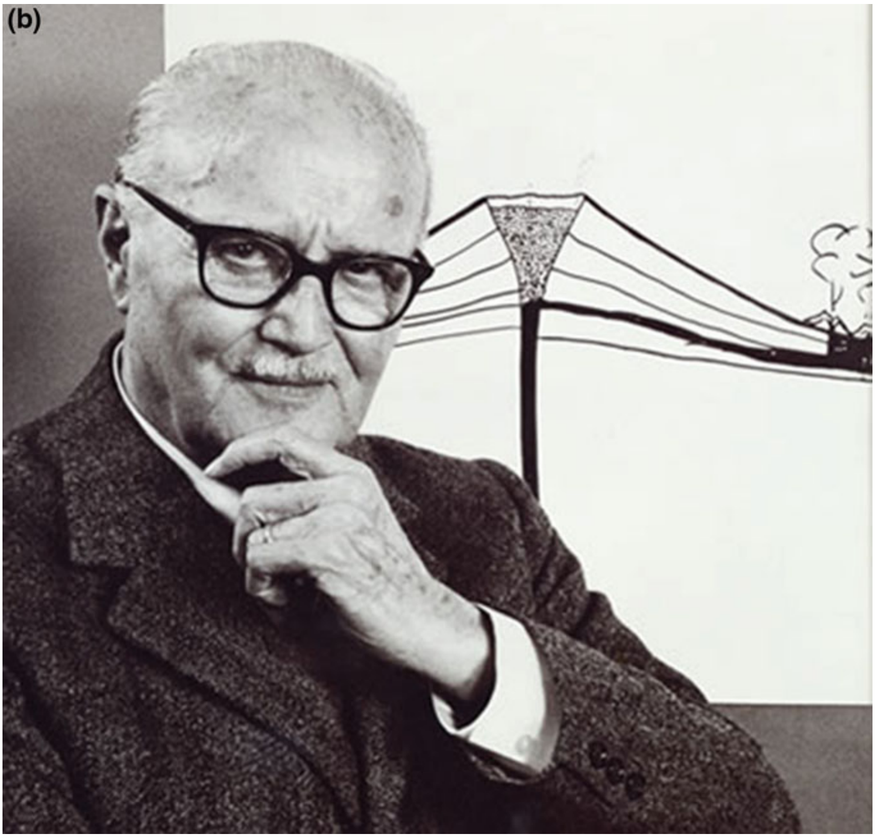


Fig. 5 (continued)

were also depicting Etnean eruptions for an international as well as a national audience. Detailed studies of eruptions were published by a number of scientists among whom were Orazio Silvestri, Annibale Riccò, Ottorino De Fiore and Gaetano Ponte. In 1926 Gaetano Ponte founded the *Etnean Volcanological Institute* within the University of Catania, and under his leadership a complete inventory of eruptive activity was maintained throughout the economically difficult 1930s and during the Second World War (see Branca and Del Carlo 2004, pp. 3–4), although until the 1950s international contacts were much reduced and there was little communication of information outside Italy other than through the pages of *Atti Accademia Gioenia di Scienze Naturali*.

The appointment in 1958 of the eminent Swiss volcanologist, Alfred Rittmann (1893–1980—Fig. 5), to the *Etnean Volcanological Institute* re-launched the international profile of volcanic studies. In 1967 with the financial support of the *Consiglio Nazionale delle Richerche* (CNR—National Research Council) and with the patronage of UNESCO, the institute became the *International Institute of Volcanology* and Rittmann encouraged collaboration between Italian, French and British scientists, that culminated in both: the production of a 1:50,000 scale geological map and memoir (Romano 1982) and the publication of a research volume (Chester et al. 1985), which grew out of this collaboration.

5 Concluding Remarks

Italy and in particularly Etna has unrivalled historical records of volcanic activity extending back well over 2500 years to classical times. There are large gaps in the record, however, with accounts dating from Greeks and Romans times being typically mythological and/or speculative and containing relatively little usable observational detail. For both Etna and the Azores it was priests who from the 16th century provided written descriptive accounts of eruptions and to a more limited extent their impact. They showed an ability not only to describe, but also to utilize their observations to develop an understanding of volcanological processes, which in the case of Canon Recupero brought him into conflict with his ecclesiastical superiors. Sicily is situated at the cross-roads of Mediterranean trade routes and the 1669 eruption of Etna attracted international interest (Azzaro and Castelli 2013). Observers showed a scientific approach in their description, observing and measuring lava flows and making comments on their impacts on local communities. Results were published first in letters and reports of limited circulation, later in research volumes and, beginning with the *English Merchants' Report* to the *Royal Society of London* in 1669, in international scientific journals (Anon 1669).

With the exception of the submarine eruption off the coast of São Miguel which was fortuitously observed by Captain Tillard, the Azores were more remote and eruptions were neither witnessed nor described by international scholars to the same extent. This remoteness, combined with the distinctive intellectual history of Portugal and the Azores, meant that, although there were major eruptions in the 16–18th centuries, documentation of activity was largely restricted to the islands, sometimes not published until much later and not communicated to the wider world to anything like the same extent as occurred on Etna. Indeed until the eruption of Capelinhos in 1957/8, there is virtually no reference to eruptions in the Azores in volcanological texts, despite better communications—steam ships and the electric telegraph—being important elements in the islands' economy from the mid-19th century.

At the global scale the ways in which information on eruptions has been communicated between 1980 and the middle of the 2010s is the subject of another chapter in this volume, but for reasons of completeness the situation in the Azores and Etna can be brought up-to-date. For the Azores the designation of Furnas as a *Laboratory Volcano* acted as a powerful stimulus and brought together a number of scholars from a variety of European countries and from a variety of disciplines, who researched topics which ranging from the 'traditional' (e.g. volcanic geology), to the innovative (e.g. hydrogeology, health hazards and human vulnerability). These were subsequently published in a special 'issue' of *Journal of Volcanology and Geothermal Research* (Duncan et al. 1999). Today volcanology in the Azores is studied both by the *Departamento de Geociências*, *Universidade dos Açores* and the university hosted: *Centro de Vulcanologia e Avaliação de Riscos Geológicos* (*CVARG* Centre of Volcanology and Evaluation of Geological Risk); and *CIVISA* (*Centro de Informação de Vigilância Sismovulcânica dos Açores* or Centre for Information and Seismovolcanic Surveillance of the Azores) (Gaspar et al. 2011). These bodies have continued to communicate information both, locally through liaison with the Civil Defence authorities, and internationally by means of publication in peer-reviewed academic volumes/journals and having a strong on-line presence (http://www.cvarg.azores.gov.pt/Paginas/home-cvarg.aspx).

The situation in Sicily is broadly similar to that in the Azores, with attention being focused, *inter alia*, on: observing and communicating information on contemporary eruptions; liaising with the Civil Defence authorities; reconstructing the impact of historic eruptions (e.g. Branca et al. 2013); geophysical monitoring of Etna and increasing public awareness. From 1999 the *International Institute of Volcanology* became a section of the *Instituto Nazionale di Geofisica e Vulcanologia*, its website is available in Italian and English (http://www.ct.ingv.it/en/) and, as in the Azores, there is a strong emphasis on international publishing and attendance at academic conferences.

Even in well studied areas, such as Japan, Hawaii, the Cascades and Italy, in 1980 the data available to the international research community were almost exclusively focused on the physical characteristics of eruptions, the spatial extent of their products and petrological aspects of lava flows and pyroclastic deposits. This deficiency was, however, becoming recognized, for example by Gordon Macdonald in his seminal book (Macdonald 1972, pp. 427) notes, 'it is time for volcanologists to put less emphasis on purely scientific aspects of their science, such as the generation and modification of magmas, and to give more attention to humanistic aspects—prediction and control of volcanic eruptions and the utilization of volcanic energy'. There were exceptions, such as Sheets and Grayson's (1979) edited volume *Volcanic Activity and Human Ecology* and Murton and Shimabakuro's (1974) paper on human adjustments to volcanic hazard in Hawaii—both published in the decade before 1980, but overall volcanology was dominated by the concerns of the geologist and igneous petrologist. Therefore, before the designation of the 1990s as the *International Decade for Natural Disaster Reduction* (*IDNDR*) and the subsequent *International Strategy for Disaster Reduction Communication* (*ISDR*) from 2000, the information communicated by means of the international peer reviewed literature was different in kind as well as being more restricted in volume. For instance in the eight years between 1982 and 1990, a survey of research output carried out in the context of the European *Laboratory Volcanoes* initiative,[23] showed that academic publication was dominated by the concerns of pure researchers, with papers in academic journals on more applied topics (i.e. prediction, social impact, policy implication and civil defence), constituting but a very small proportion of the total (Chester et al. 2002, pp. 419–420). Similar comments apply to other volcanic regions, with much of the information on social impact and civil protection being restricted to official reports and conference papers. This 'grey literature' was neither widely known outside its country of origin nor was it peer—reviewed by members of the international research community. Today in the wake of the *IDNDR* and the current *ISDR*, not only has volcanology become more focused on hazard reduction, but the personnel has also widened to include social scientists, health professionals and experts in civil defence (Chester 2005).

[23]This was an initiative of the European Union/European Science Foundation during the 1990s. The volcanoes chosen for detailed study were: Mount Etna; Furnas (São Miguel, Azores); Piton da la Fournaise (Réunion, Indian Ocean); Teide (Tenerife) and Santorini (Greece). Later Krafla in Iceland was added. This initiative paralleled the 'Decade Volcanoes' research programme sponsored by IAVCEI.

References

Abate T, Branca S, Monaco C (2013) Le eruzione dell'Etna nell'opera di Orazio Silvestri (1835–1890): Il disegno come strumento per l'osservazione scientifica. Caracol, Palermo

Admiralty (1945) Spain and Portugal, The Atlantic Islands (Br 502, vol 5). Naval Intelligence Division, London

Agostinho J (1932) Vulcanismo dos Açores. Vista geral. A Terra 4:32–36

Akasoy A (2007) Islamic attitudes to disaster in the middle ages: a comparison of earthquakes and plagues. Medieval Hist J 10(1–2):387–410

Alessi G (1829–1835) Storia delle eruzione dell'Etna. *Atti Accademia Gioenia di Scienze Naturali Catania* Ser.1 (3): 17–75; (4): 23–74; (5): 43–72; (6): 85–116; (7): 21–65; (8): 99–148 and (9): 127–206

Anon (1669) An answer to some inquiries concerning the eruption of Mount Aetna, An. 1669. Communicated by some inquisitive English merchants, now residing in Sicily. Phil Trans R Soc Lond 4:1028–1034

Anon (1809) Letter from an officer of he 27th regiment dated 12th April 1809. Caledonian Mercury, June 19 (Issue 13653)

Anon (1865) The eruption of Etna. Boston daily advertiser March 7 (Issue 56), column F (no page numbers)

Anon (1923) Etna eruption ends. June 26 crater still active. Trainloads of sightseers. The Times (London), June 26, p 12, column c

Anon (2014a) Tommaso Fazello. L Enciclopedia Italiana. Treccani.it. http://www.treccani.it/enciclopedia/tag/tommaso-fazello/. Accessed 18 July 2014

Anon (2014b) Antonio Filoteo (or Antonio Filoteo degli Omodei) L Enciclopedia Italiana. Treccani.it. http://www.treccani.it/enciclopedia/antonio-filoteo-degli-omodei. Accessed 28 May 2014

Anon (2014c) Pietro Carrera. http://en.wikipedia.org/wiki/Pietro_Carrera. Accessed 28 May 2014

Anon (2015) Mount Cameroon. University of Oregon. http://volcano.oregonstate.edu/oldroot/volcanoes/cameroon/. Accessed 7 Apr 2015

Ashe T (1813) The history of the Azores or Western Islands. Sherwood, Neely and Jones, London

Auker MR, Sparks RSJ, Siebert L et al (2013) A statistical analysis of the global historical volcanic fatalities record. J Appl Volcanol 2(2): 24 p. http://www.appliedvolc.com/content/2/12
Azzaro R, Castelli V (2013) L' eruzione etnea del 1669 nelle relazioni giornalistiche contemporanee. INGV, Le Nove Muse Editrice, Catania
Balmuth MS, Chester DK, Johnston PA (2005) Cultural responses to the volcanic landscape: the mediterranean and beyond. Archaeological Institute of America, Boston
Blong RA (1982) The time of darkness, local legends and volcanic reality in Papua New Guinea. University of Washington Press, Seattle and Australian National University Press, Canberra
Blong RA (1984) Volcanic hazards. Academic Press, Sydney
Booth B, Croasdale R, Walker G (1978) A quantitative study of five thousand years of volcanism on S. Miguel, Azores. Phil T R Soc Lond 228:271–319
Borelli GA 1670 (reprinted 2001) Storia e meteorologia dell'eruzione dell'Etna dell 1669. Giunti, Firenze
Branca S, Azzaro R, De Beni E, Chester D, Duncan A (2015) Impacts of the 1669 and the 1693 earthquakes of the Etna Region Eastern Sicily, Italy: an example of recovery and response of a small area to extreme events. J Volcanol Geoth Res 303:25–40
Branca S, Del Carlo P (2004) Eruptions of Mt. Etna during the past 3,200 years: a revised compilation integrating the historical and stratigraphic records. In: Bonaccorso A, Calvari S, Coltelli et al (eds) Mt. Etna Volcano Laboratory, vol 143. Geophysical Monograph Series, American Geophysical Union, Washington DC, pp 1–27
Branca S, Coltelli M, Groppelli G et al (2011) Geological map of Etna volcano, 1:50,000 scale. Ital J Geosci 130:265–291
Branca S, De Beni E, Proietti C (2013) The large and destructive 1669 AD eruption at Etna volcano: reconstruction of the lava flow field evolution and effusion rate trend. Bull Volcanol 75:694. doi:10.1007/s00445-013-0694-5
Brydone P (1773) A tour through Sicily and Malta. W. Strahan and T. Cadell, London
Callender JM, Henshall JD (1968) The land use of Faial in the Azores. In: Cook AN (ed) Four island studies. The world land use survey, Monograph 5. Geographical Publications Ltd., Bude, Chapter II, p 23
Carneiro A, Simões A, Diogo MP, Mota TS (2013) Geology and religion in Portugal. Notes Rec R Soc 67:331–354
Carrera P (1636) Il Mongibello descritto in tre libri. G. Rossi, Catania
Cashman KV, Giordano G (2008) Volcanoes and human history. J Volcanol Geotherm Res 176:325–329
CAVW (1951–1975) Catalogue of active volcanoes of the world. International association of volcanology and chemistry of the earth's interior, Napoli, vol 1–22
Chester DK (2005) Volcanoes, society and culture. In: Marti J, Ernst GJ (eds) Volcanoes and the environment. Cambridge University Press, Cambridge, pp 404–439
Chester DK, Duncan AM, Guest JE, Kilburn CRJ (1985) Mount Etna: the anatomy of a volcano. Chapman and Hall, London
Chester DK, Duncan AM, Guest JE, Johnston PA, Smolenaars JJL (2000) Human responses to Etna volcano during the classical period. In: McGuire WG, Griffiths DR, Hancock PL, Stewart IS (eds) The archaeology of geological catastrophes. Geological Society of London, Special Publication 171, pp 179–188
Chester DK, Dibben CJL, Duncan AM (2002) Volcanic hazard assessment in Western Europe. J Volcanol Geotherm Res 115:411–435
Chester DK, Duncan AM, Dibben CRJ (2008) The importance of religion in shaping volcanic risk perceptions in Italy, with special reference to Vesuvius and Etna. J Volcanol Geotherm Res 172:216–228
Chester DK, Duncan AM, Sangster H (2012) Human responses to eruptions of Etna (Sicily) during the late-Pre-Industrial Era and their implications for present-day disaster planning. J Volcanol Geotherm Res 225–226:65–80
Coltelli M, Del Carlo P, Vezzoli L (1998) The discovery of a Plinian basaltic eruption of Roman age at Etna volcano, Italy. Geology 26:1095–1098
Coutinho R, Chester DK, Wallenstein N et al (2010) Responses to, and the short and long-term impacts of the 1957/1958 Capelinhos volcanic eruption and associated earthquake activity on Faial, Azores. J Volcanol Geotherm Res 196:265–280
Crosweller HS, Arora B, Brown SK et al (2012) Global database on large magnitude explosive volcanic eruptions (LaMEVE). J Appl Volcanol 1:4. http://www.appliedvolc.com/content/1/1/4
De Meneses A de F (2012) The discovery. In: Simas RM (trans) Cultural itinerary of the Azores. Regional Directorate for Culture, Governo dos Açores, Ponta Delgada
Degg M, Doornkamp J (1994) Earthquake hazard atlas: 7. Iberia (Portugal and Spain). London Insurance and Reinsurance Market Association, London
Deligne NI, Coles SG, Sparks RSJ (2010) Recurrence rates of large explosive volcanic eruptions. J Geophys Res 115:B06203. doi:10.1029/2009JB006554
Dias U de M (1931) Literatos dos Açores—Estudo histórico sobre os escritores açorianos. Emp. Tipografico Vila-Franca do Campo, Ponta Delgada
Duncan AM, Gaspar JL, Guest JE et al (1999) Furnas Volcano, São Miguel, Azores. J Volcanol Geotherm Res 92 (1–2), special volume, p 214
Duncan AM, Chester DK, Guest JE (2005) Eruptive activity of Etna before A.D. 1600, with particular reference to the classical period. In: Balmuth MS, Chester D, Johnston PA (eds) Cultural responses to the volcanic landscape. Archaeological Institute of America Colloquia and conference papers 8, Boston, pp 57–69

Fazzello T (1558) De Rebus Sicilis decades duae, nunc primum in lucum editae, his accessit totius operis index locupletissimus. Folio Panormi, Catania

Ferrara F (1818) Descrizione dell' Etna, con la storia delle eruzione e il catalogo dei prodotti. Lorenzo Dias, Palermo

Filoteo A (1590) Aetna topografia atque ejus incendirum istoria. Folio, Perugia

Firth CR, McGuire WJ (1999) Volcanoes in the quaternary. Geological Society Special Publication 161, Geological Society, London

Foster BR (1996) Volcanic phenomena in Mesopotamian sources. Appendix B. In: Polinger-Foster K, Ritner RK (eds) Texts, storms and the Thera eruption. J Near East Stud 55(1):1–14

Frutuoso G (2005) Saudades da Terra. Instituto, Cultural de Ponta Delgada, Pont Delgada, Açores

Fuchs CW (1865) Die vulkanischen Erscheinungen der Erde. Verlagsort, Leipzig

Furlan C (2010) Extreme value methods for modelling historical series of large volcanic magnitudes. Stat Modell 10(2):113–132

Furneaux R (1965) Krakatoa. Secker and Warburg, London

Gaspar JL, Queiroz G, Ferreira T, Amaral P, Viveiros F, Marques R, Silva C, Wallenstein N (2011) Geological hazards and monitoring at the Azores (Portugal). In: Earthzine—fostering earth observation and global awareness. http://www.earthzine.org/2011/04/12/geological-hazards-and-monitoring-at-the-azores-portugal/. Accessed 1 June 2014

Gaspar JL, Queiroz G, Ferreira T, Medeiros AR, Goulart C, Medeiros J (2015) Earthquakes and volcanic eruptions in the Azores region: geodynamic implications from major historical events and instrumental seismicity. In: Gaspar JL, Duncan AM, Chester DK (eds) Volcanic Geology of São Miguel Island (Azores Archipelago). Geological Society, London

Gemmellaro C (1858) La vulcanolgia dell'Etna. Tipografia dell'Accademia Gioenia, Catania

Grattan J (2006) Aspects of Armageddon: an exploration of the role of volcanic eruptions in human history and civilization. Quat Int 151:10–18

Grattan J, Torrence R (2007) Living under the shadow. The cultural impacts of volcanic eruptions. Left Coast Press, Walnut Creek, California

Guest JE, Gaspar JL, Cole PD et al (1999) Volcanic geology of Furnas Volcano, São Miguel, Azores. J Volcanol Geotherm Res 92:1–29

Guest J, Cole P, Duncan A, Chester D (2003) Volcanoes of Southern Italy. Geological Society, London

Gushchenko II (1979) Eruptions of volcanoes of the world: a catalog. Academy of USSR Far East Science Center. Nauka Publishing, Moscow

Harris SL (2000) Archaeology and volcanism. In: Sigurdsson H, Houghton B, Mc Nutt SR, Rymer H, Stix J (eds) Encyclopedia of volcanoes. Academic Press, San Diego, pp 1301–1314

Hodder I (2015) Personal communication Professor Ian Hodder Stanford University, California, dated 28 Mar 2015

Inwood MJ (1995) Enlightenment. In: Honderich T (ed) The Oxford companion to philosophy. Oxford University Press, Oxford, pp 236–237

Johnston PA (2005) Volcanoes in classical mythology. In: Balmuth MS, Chester DK, Johnston PA (eds) Cultural responses to the volcanic landscape. Archaeological Institute of America Colloquia and conference papers 8, Boston, pp 297–310

Keys D (1999) Catastrophe: an investigation into the origins of the modern world. Century, London

Lacroix A (1904) La Montagne Peleé et ses éruption. Masson et Cie, Paris

Lamb HH (1970) Volcanic dust in the atmosphere; with a chronology and assessment of its meteorological significance. Phil T R Soc A 266:425–533

Luz JB (1996) O homem e a história em Gaspar Frutuoso. Homenagem ao Prof. Doutor Lúcio Craveiro da Silva. Rev Port Filosofia 52:475–486

Lyell C (1830) Principles of geology. John Murray, London

Macdonald GA (1972) Volcanoes. Prentice Hall, Englewood Cliffs, New York

Machado F, Richards AF, Mulford JW et al (1962) Capelinhos eruption of Fayal volcano Azores. J Geophys Res 67(9):3519–3529

McCoy F, Heiken G (2000) Introduction. In: Mc Coy F, Heiken G (eds) Volcanic hazards and disasters in human antiquity. Geological Society of America special paper 345, Boulder CO, pp v–vi

McGuire WJ, Griffiths DR, Hancock PL, Stewart IS (2000) The archaeology of geological catastrophes. Geological Society Special Publication 171, Geological Society, London

Mellaart J (1967) Çatal Hüyük: a Neolithic town in Anatolia. Thames and Hudson, London

Mercalli G (1907) I vulcani attivi della terra: morfologia, dinamismo, prodotti, distribuzione geografica. Hoepli, Milano

Monaco F (1669) Cataclysmus aetnaeus sive inundation ignea Aetnae montis anni. Hertz, Venezia

Mota TS, Carneiro A (2013) 'A time for engineers and a time for geologists': scientific lives and different pathways in the history of Portuguese geology. Earth Sci Hist 32(1):23–38

Murton BJ, Shimabakuro S (1974) Human adjustment to volcanic hazard in the Puna district, Hawaii. In: White GF (ed) Natural hazards: local, national, global. Oxford University Press, New York, pp 151–161

Neumann van Padang M, Richards AF, Machado F, Bravo T, Baker E, Le Maitre W (1967) Atlantic ocean: catalogue of the active volcanoes of the world. International Association of Volcanology, Rome, Italy, Part XXI

Newhall CG, Self S (1982) The Volcanic Explosivity Index (VEI): an estimate of the explosive magnitude for historical volcanism. J Geophys Res 87(C):1231–1238

Nolan ML (1979) Impact of Parícutin on five communities. In: Sheets PD, Grayson DK (eds) Volcanic activity and human ecology. Academic Press, New York, pp 293–335
Oppenheimer C (2011) Eruptions that shook the world. Cambridge University Press, Cambridge
Polinger-Foster K, Ritner RK (1996) Texts, storms and the Thera eruption. J Near East Stud 55(1):1–14
Queiroz G, Gaspar JL, Cole PD, Guest JE et al (1995) Erupções vulcânicas no valle das Furnas (Ilha de S. Miguel, Açores), na primeira metade do seculo XV. Açoreana 8(1):159–165
Recupero G (1815) Storia naturale e generale dell'Etna. Ed. Dafni, Tringale Editore (Catania 1970)
Rodrigues R (1991) Notícia Biográfica do Dr. Gaspar Frutuoso. Cultural Institute of Ponta Delgada, Ponta Delgada
Rodwell GF (1878) Etna: a history of the Mountain and its eruptions. Kegan Paul, London
Romano R (ed) (1982) Mount Etna Volcano. Memorie Della Società Geologica Italiana XXIII
Romano R, Sturiale C (1982) The historical eruption of Mt. Etna (volcanological data). In: Romano E (ed) Mount Etna Volcano. Estratto da Memorie Della Società Geologica Italiana XXIII, pp 75–97
Sapper KT (1917) Katalog der geschichtlichen Vulkanausbrüche. Karl J. Trubner, Strasburg
Schneider K (1911) Die vulkanischen Erscheinungen der Erde. Gebrüder Borntraeger, Berlin
Scrope GP (1825) Considerations of volcanoes: the probable causes of their phenomena, the laws which determine their march, the disposition of their products, and their connexion with the present state and past history of the globe; leading to the establishment of a new theory of the Earth. W. Phillips, London
Scrope GP (1862) Volcanoes: the character of their phenomena, their share in the structure and composition of the surface of the globe, and their relation to its internal forces. Longman, Green, Longmans and Robert, London
Seibert L, Simkin T, Kimberly P (2010) Volcanoes of the world, 3rd edn. Smithsonian Institution, Washington DC
Sheets PD, Grayson DK (1979) Volcanic activity and human ecology. Academic Press, New York
Sigurdsson H (1999) Melting the Earth: the history of ideas on volcanic eruptions. Oxford University Press, New York and Oxford
Sigurdsson H (2000) The history of volcanology. In: Sigurdsson H, Houghton BF, McNutt SR, Rymer H, Stix J (eds) Encyclopedia of volcanoes. Academic Press, San Diego, pp 15–37
Simkin T (1993) Terrestrial volcanism in space and time. Annu Rev Earth Planet Sci 21:427–452
Simkin T (1994) Distant effects of volcanism—how big and how often. Science 264:913–914
Simkin T, Fiske R (1983) Krakatau 1883: the volcanic eruption and its effects. Smithsonian Institution, Washington DC
Simkin T, Siebert L (1994) Volcanoes of the world, 2nd edn. Smithsonian Institution, Washington DC
Simkin T, Siebert L (2000) Earth's volcanoes and eruptions: an overview. In: Sigurdsson H, Houghton BF, McNutt SR, Rymer H, Stix J (eds) Encyclopedia of volcanoes. Academic Press, San Diego, pp 249–261
Simkin T, Siebert L, McClelland L, Bridge D, Newhall C, Latter JH (1981) Volcanoes of the world. Smithsonian Institution, Washington DC
Simkin T, Siebert L, Blong R (2001) Volcano fatalities—lessons from the historical record. Science 291:255
Simões A, Carneiro A, Diogo MP (2012) Riding the wave to reach the masses: natural events in the early twentieth century Portuguese daily press. Sci Educ 21:311–333
Smolenaars JJL (2005) Earthquakes and volcanic eruptions in Latin literature: reflections and emotional responses. In: Balmuth MS, Chester DK, Johnston PA (eds) Cultural responses to the volcanic landscape. Archaeological Institute of America Colloquia and conference papers 8, Boston, pp 311–329
Squillaci P (1669) Relatione del fuoco di Mongibello, e di quel che segui. Stamperia del Dragondelli, Roma
Stone C (2003) Doctor, philosophy and renaissance man, Saudi Aramco World, pp 8–15
Tanguy J-C, Ribière Ch, Scarth A et al (1998) Victims of volcanic eruptions: a revised database. B Volcanol 60:137–144
Tanguy J-C, Condomines M, Branca S et al (2012) New archeomagnetic and ^{226}Ra-^{230Th} dating of recent lavas for the geological map of Etna volcano. Ital J Geosci 131:241–257
Tazieff H (1983) Some general points about volcanism. In: Tazieff H, Sabroux JC (eds) Forecasting volcanic events. Developments in volcanology, vol 1. Elsevier, Amsterdam, pp 9–25
Tedeschi释Paternò T (1669) Breve Raguaglio degl'Incendi di Mongibello avvenuti in quest'anno 1669. Egidio Longo, Napoli
Tillard S (1812) A narrative of the eruption of a volcano in the sea off the Island of St. Michael. Phil T R Soc 102:152–158
Vaccari E (1998) Lyell's reception on the continent of Europe: a contribution to an open historiographical problem. Geological Society of London Special Publication 143, pp 39–52
Vaccari E (2008) "Volcanic travels" and the development of volcanology in 18th century Europe. Proc California Acad Sci 59 (suppl. 1:3):37–50
Varen PR (1650) Geographia generalis, in qua affections generales telluris explicantur. L Elzevirium, Amstelodami
Verbeek RDM (1884) Kort verslag over de uitbarsting van Krakatau op 26, 27 en 28 Augustus 1883. Landsdrukkerij, Batavia
von Hoff KEA, Berghaus HKW (1840/1841) Chronik der Erdbeben und Vulcan-Ausbrüche mit vorausgehender Abhandlung über die Natur dieser Ercheinungen. Bei J Perthes, Gotha, 2. Vols

von Humboldt A (1858) Kosmos: Entwurf einer physischen Weltbeschreibung. Mit einer boigraphischen Einleitung, vol 5. J.G. Cotta, Stuttgart

von Waltershausen WS (1844–1859) Atlas des Aetna. Vandenhoeck, Göttingen and Berlin

Walker GPL, Croasdale R (1971) Two Plinian-type eruptions in the Azores. Q J Geol Soc Lond 127:17–55

Weston FS (1964) A list of recorded volcanic eruptions in the Azores with brief reports. Boletim do Museu e Laboratório Mineralógico e Geológico da Faculdade de Ciêcias, Universidade de Lisboa 10:3–18

Winchilsea (Earle of) (1669) A true and exact relation of the late prodigious earthquake and eruption of Mount Etna or Montegibello as it came in a letter written to his majesty from Naples. Together with a more particular narrative of the same, as it is collected out of several relations sent from Catania. Newcomb, London

Witham CS (2005) Volcanic disasters and incidents: a new database. J Volcanol Geotherm Res 148:191–233

Zbyszewski G (1961) Étude geologique de l'ile de S. Miguel (Açores). Comunicações Serviços Geológicos de Portugal 45:5–79

Zbyszewski G, Moitinho de Almeida F, Veiga Ferreira O, Torre de Assunção C (1958) Notícia explicativa da Folha "B", da ilha S. Miguel (Açores) da Carta Geológica de Portugal na escala 1:50000. Serviços Geológicos de Portugal, Lisboa

Zbyszewski G, Ferreira OV, Assunção CT (1959) Notícia explicativa da Folha "A", da ilha S. Miguel (Açores) da Carta Geológica de Portugal na escala 1:50000. Publ. Serviços. Geológicos de Portugal, Lisboa